

A PRESSURE SENSOR, A METHOD FOR MANUFACTURING A PRESSURE
SENSOR AND A COMBUSTION ENGINE HAVING A PRESSURE SENSOR

FIELD OF THE INVENTION

The present invention relates to a pressure sensor, a method for manufacturing a pressure sensor, and an internal combustion engine having a pressure sensor.

5

BACKGROUND INFORMATION

Pressure sensors are used in various branches of engineering in order to measure the pressures of gases or liquids. The pressure sensors are often subjected to high loads that depend on the current state of the medium in which the measurement is performed. Frequently, the pressures acting on the pressure sensor vary considerably. A pressure sensor must therefore withstand high loads, and it must deliver exact measuring results.

Conventional pressure sensors include a diaphragm, which deforms in response to a pressure difference on the two sides of the diaphragm. The deformation of the diaphragm is measured by piezoelectric elements, which are situated on one side of the diaphragm.

In the case of high pressure or temperature loads, there is the problem of the pressure-sensor diaphragm twisting or warping in its frame or suspension. The consequences include inaccurate measurements or invalid measuring results, which occur in response to high pressure or temperature fluctuations.

Therefore, it is an object of the present invention to provide a pressure sensor, which delivers accurate measuring results, and may be configured so that it withstands high pressures, and functions reliably in the case of large pressure or temperature differences. It is another object of the present invention to provide a method for manufacturing such a pressure sensor which may be implemented quickly and

cost-effectively. It is a further object of the present invention to provide a combustion engine that may attain lower emissions and/or an improved efficiency.

5 SUMMARY

The above and other beneficial objects of the present invention are achieved by providing a pressure sensor, a method for manufacturing a pressure sensor and a combustion engine as described herein.

10 The pressure sensor according to the present invention includes a housing, the interior chamber of which is sealed by a diaphragm, an arrangement configured to generate a signal in response to the diaphragm being deformed, and also a flexible measuring element, which is included in addition to, i.e.,
15 positioned separately from the diaphragm, and is coupled to the diaphragm. The arrangement configured to generate a signal being coupled to the flexible measuring element, in order to generate the measuring signal in response to the flexible measuring element deforming.

20 The pressure sensor according to the present invention prevents the measuring results from being invalidated by twisting or warping of the diaphragm. The additional, flexible measuring element positioned separately from the diaphragm allows measuring results to be achieved, which are
25 still relatively accurate, even in the case of a diaphragm that is twisted or warped in itself. The pressure sensor may even perform accurate and reliable measurements in the case of high pressures or pressure differences, and/or in the case of sharply changing temperatures, the pressure sensor also having
30 an increased service life.

35 The measuring element may include a bendable bar, one end of which is freely suspended. In this manner, a deformation of the diaphragm, which is caused by a pressure acting on the diaphragm, may be transmitted to the bendable bar, and the pressure may be picked up and measured separately from the deformation of the diaphragm. The measuring or deformation element may, for example, be formed in the shape of a tongue.

10650533-0104
15050500

The measuring signal is generated by the deformation of the measuring element. The bar may relax in response to undesired twisting or warping. This prevents the measuring results from being invalidated. In addition, the pressure sensor may include a stop element, which opposes the deformation force in response to a selected deformation of the measuring element. This arrangement provides overload protection against high pressures, the overload protection being independent of the output signal. That is, the measuring element may be designed for high sensitivity and nevertheless withstand relatively high pressures. Therefore, there is no loss of sensitivity at the measuring element, even in the case of high pressure loads. The pressure sensor may also measure the applied pressure under high pressure loads, without the danger of destroying the measuring element. The stop element may be rigid, so that the measuring element does not bend or deform further upon reaching the stop, or the stop element may be designed to be bendable or flexible.

The stop element may be in the form of a second, flexible measuring element, which, for example, is harder or flexurally stiffer than the first measuring element. This arrangement allows the pressure sensor to have a plurality of measuring ranges and to be, e.g., suitable for measuring in the low pressure range and also, or simultaneously, in the high pressure range. At relatively low pressures, only the first measuring element is initially deformed. The stop element or second, flexible measuring element also deforms at or beyond a selected deformation of the first measuring element.

Because of the high resistance of the stop element or second measuring element, the first measuring element only bends or deforms a little more, even at high, applied pressures, so that it is protected from overload. Thus, at or above a selected pressure, it is only possible to further deform the first and the stiffer, second measuring elements at relatively high pressures. Therefore, the second measuring element opens up an additional measuring range for relatively high pressures.

1
2
3
4
5 The stop element may be configured as a half-open or
semiencllosed diaphragm, or it may be tongue-like or a bendable
bar, the end of which may be freely suspended. The stop
element may be fixed on one end. The stop bar may be
configured similarly to or exactly like the first measuring
element.

6
7
8
9
10 The first measuring element and/or the second measuring
element may be provided with one or more piezoelectric
elements as the arrangement configured to generate signals.
For example, the signal generation arrangement may include
piezoresistors, which may be connected to a Wheatstone bridge.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211

two measuring elements being disposed in a single chip, which consequently forms a measuring chip.

The pressure sensor may have at least two measuring ranges, e.g., the first measuring range covering a range of 0 to 20 bar, e.g., 0 to 10 bar or 0 to 2 bar, while, e.g., the second measuring range covers a range of 0 to 300 bar, e.g., 0 to 250 bar or 0 to 200 bar.

The pressure sensor may have overload protection, which, for example, may be in the range of 250 bar.

The deformable or flexible diaphragm may be manufactured from steel. This arrangement allows the diaphragm to be connected to the housing in a particularly effective and secure manner, e.g., by welding. In the case of using steel or metal as a material for the diaphragm and the housing, the thermal coefficients also match each other very well, so that the measurement accuracy and stability are also high in the case of variable temperatures or temperature fluctuations.

At least one of the elements of the pressure sensor, e.g., diaphragm, transmission element, measuring element, and/or stop element, may be manufactured with an aiming-off allowance in order to compensate for manufacturing tolerances during coupling, the diaphragm being lightly curved to the outside due to the aiming-off allowance.

Furthermore, the present invention provides a method for manufacturing the pressure sensor, the method include the steps of: providing a housing having an interior chamber, which is sealed or may be sealed by a diaphragm; providing a support structure, which, for example, supports at least one bendable or flexible measuring element on its upper side; inserting the support structure along with the bendable measuring element into the housing; and sealing the interior chamber. Using this method, a pressure sensor having a high measurement accuracy may be manufactured in a relatively simple and, therefore, inexpensive manner. The method may be used for manufacturing a pressure sensor as described above.

A stop element or a second bendable measuring element, which, in the installed state, opposes a deformation force at

or above a predetermined pressure on the diaphragm, may be on the support structure or its upper side.

During manufacturing, manufacturing tolerances may be compensated for by an aiming-off allowance, and the diaphragm, for example, is slightly pressed to the outside by the transmission element or another component part. This allows a high degree of accuracy to be achieved over the entire measuring range, even when the component parts are not exact.

The support structure or base plate may be fixed in place, preferably by a sleeve or a ring, after, e.g., inserting, introducing or mounting the support structure. The diaphragm may be welded to the housing.

The pressure sensor according to the present invention may measure the applied pressure under high pressure loads with a high degree of accuracy. The pressure sensor may be designed to simultaneously measure high and low pressures, the pressure sensor also having a high resolution in the low pressure range. Measurements may be taken in the high and low pressure ranges without costly, additional arrangements, such as, e.g., various pieces of electronic amplifying equipment. The time and the costs are especially reduced, since it is not necessary to switch over between ranges. In addition, the pressure sensor only requires a small space.

An application may include in determining the combustion chamber pressure or cylinder pressure in an internal combustion engine, in order to improve combustion or achieve an improved efficiency in conjunction with a suitable control system. For example, the pressure is accurately measured during the intake or exhaust stroke, the pressure sensor simultaneously withstanding the high pressures occurring in the combustion chamber during the combustion process. In this context, any such engine, e.g., an Otto or diesel engine, may include such a pressure sensor. The pressure sensor may, for example, be arranged in the wall of an engine cylinder.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross-sectional view of an example embodiment of a pressure sensor according to the present invention.

Figure 2 is a schematic plan view of a measuring chip of the pressure sensor according to the present invention, the measuring chip having two measuring elements.

Figure 3 is a schematic perspective view of a transmission element in the form of a chip.

Figures 4a to 4c are schematic cross-sectional views of a pressure sensor in three different states in accordance with another example embodiment of the present invention.

Figure 5 is a schematic plan view of a measuring chip of the pressure sensor having a semienclosed diaphragm as a second measuring element in accordance with still another example embodiment of the present invention.

Figure 6 is a schematic cross-sectional view of the measuring chip illustrated in Figure 5 taken along line A - A'.

DETAILED DESCRIPTION

Figure 1 is a schematic cross-sectional view of a pressure sensor 10. Pressure sensor 10 includes a housing 11, which encloses an interior chamber 12. The upper side of pressure sensor 10 includes a diaphragm 13, which seals interior chamber 12 from above. Situated in interior chamber 12, underneath diaphragm 13, is a separate measuring element 20, which is mechanically coupled to diaphragm 13 and spatially separated from diaphragm 13. A pressure difference between the outside and the interior chamber causes diaphragm 13 to deform, and the coupling causes the measuring element 20 coupled to diaphragm 13 to simultaneously deform.

A transmission element 30, which is arranged between diaphragm 13 and measuring element 20, is configured to transmit a force applied externally to diaphragm 13 to measuring element 20. An elevation or a projection arranged on the upper side of transmission element 30 in the center is

configured to mechanically couple transmission element 30 to diaphragm 13, and additional steel protuberance 42 being disposed between the elevation and diaphragm 13. Protuberance 42 forms a center-boss structure or a transmission element, in order to transmit the force to transmission element 30 in response to an externally applied pressure on diaphragm 13. Transmission element 30 is also in the form of a diaphragm, which is fixed in position on its edges, and the center of which may deflect.

With its circular shape, transmission element 30 includes an edge region 23, which is thicker than the adjoining regions, and extends down, so that transmission element 30 is set apart from a subjacent chip 38, only a region 31 in the center of transmission element 30 touching measuring element 20. However, the transmission element does not have to be circular. Transmission element may, for example, be rectangular, square, or elliptical. A stop element 35 is also arranged on the side of the transmission element on which measuring element 20 is disposed. But in contrast to measuring element 20, stop element 35 is arranged at a distance d from region 31 of transmission element 30. Distance d is selected to be so large that stop element 35 only comes into contact with region 31 at or above a certain external pressure on diaphragm 13. That is, region 31 only touches stop element 35 at or beyond a selected deformation of measuring element 20. This arrangement prevents measuring element 20 from bending further or only allows it to continue bending when an increased force or pressure is applied to diaphragm 13.

In the example embodiment of the present invention illustrated, stop element 35 is configured to be flexible or configured as a bendable bar, like measuring element 20. However, it may also be configured to be rigid in order to be used purely as overload protection. Measuring element 20 and stop element 35 are positioned on a base plate 40 or support structure, which forms an electrical bushing or feed-through lead. The electrical bushing seals cylindrical housing 11 in

a pressure-tight manner from below, i.e., from the side opposite diaphragm 13. Base plate 40 has a circular cross-section in order to fit onto the inside of the wall of cylindrical housing 11. Provided in base plate 40 or in the electrical bushing is a sleeve 41, through which an electrical connection or line 41a is fed in a pressure-tight manner into interior chamber 12 to measuring element 20 and possibly to stop element 35.

Measuring element 20 and stop element 35 are components of chip 38, which may be manufactured from silicon. However, other suitable materials may be used for this purpose. The chip surface and the upper surface of measuring element 20 are on the same level, while a region of chip 38 has a lower-lying surface thereby forming stop element 35, which only comes into contact with region 31 of transmission element 20 at or above a certain pressure that acts externally on diaphragm 13. However, it is possible to design measuring element 20 and stop element 35 to be on the same level and to provide gradations or steps or different levels on transmission element 30 so that transmission element 30 only comes into contact with stop element 35 at or above a certain pressure.

Measuring element 20 is thinner than the rest of chip 38 so that its front end is suspended freely over base plate 40 and it may be bent down through transmission element 35 in the direction of base plate 40 in response to a force acting from above. The piezoelectric measuring element 20 configured as a bending bar may be, for example, configured to be relatively thin and flexible for measurements in the low pressure range, e.g., in the range of 0 to 10 bar or in the range of 0 to 2 bar, so that its piezoelectric elements achieve a high measurement accuracy and resolution for this range of relatively low pressure.

In the example embodiment of the present invention illustrated, stop element 35 is in the form of a bar or tongue, which is substantially similar to or the same as measuring element 20 described above. However, the stop element is configured to have a greater hardness or stiffness,

which, for example, may easily be achieved over the length and/or the width. It forms a second measuring element, which is suitable for measurements in the range of higher pressures, e.g., in the range of up to 300 bar or up to 200 bar.

5 However, other ranges are also possible. The stop element is simultaneously used as stop, as is described above.

Therefore, the combination with first measuring element 30 results in a low pressure range of 0 to 10 bar or 0 to 2 bar, with high resolution, and a high pressure range of 0 to 300
10 bar or 0 to 200 bar, with a lower resolution. Therefore, the sensor has two different measuring ranges, each of which provides the best possible resolution.

Schematically illustrated in Figure 2 is chip 38, in which measuring element 20 and stop element 35 are integrated or provided. Chip 38 is manufactured using micromechanics or microtechnology. A bar or tongue is patterned in a subsection of chip 38 to form measuring element 20 and stop element 35. Openings or recesses, which, e.g., may accommodate pins for wire bonding, are provided on both sides, on one side or on the side of measuring element 20 and stop element 35.

Measuring element 20 and stop element 35 include piezoelectric elements or piezoresistors 21, which are connected to a Wheatstone bridge and form an arrangement for signal generation. Therefore, an electrical signal is
25 generated in response to measuring element 20 or stop element 35 bending, deforming, or elongating. In this context, the signal generation is a function of the degree of deformation or elongation of measuring element 20 or stop element 35, which is caused by the external pressure acting on diaphragm
30 13.

Figure 3 is a schematic perspective view of transmission element 30 from below. Transmission element 30 is a diaphragm, which is manufactured by microtechnology or micromechanics, and includes an elevation or projection on
35 both the upper and lower sides of its center. The elevation on the lower side forms region 31, which is in contact with the bending bar or piezoelectric measuring element 20, and

bends it downwardly in response to a compressive force acting on diaphragm 13 from above.

The thickness or stiffness of transmission element 30 or the transmission diaphragm directly affects the measuring range of the pressure sensor. Therefore, the measuring range may be controlled by varying the thickness of transmission element 30. Transmission element 30 and stop element 35 provide a multiple overload protection for the sensor, without a loss of sensitivity at the measuring chip or measuring element 20. In this context, the overload protection is independent of the output signal, and the silicon bending bar or measuring element 20 may expand to the limit so that the result is a very high sensitivity.

The functioning principle of the multirange pressure sensor according to a further example embodiment of the present invention is described below with reference to Figures 4a to 4c.

Without illustrating the housing, Figure 4a illustrates a state in which no pressure is applied. The two measuring elements 20, 35 or deformation elements are not deformed.

Upon application of an external pressure, which is greater than the pressure in interior chamber 12, the pressure difference causes diaphragm 13 to bend downwardly, i.e., in the direction of interior chamber 12. In this manner, the center of transmission chip 30, which is coupled to diaphragm 13, is pressed down and thus transmits the force to measuring element 20, which consequently bends. In response to a low pressure, e.g., between 0 and 2 bar, measuring element 20 bends through region 31 of transmission element 30, without stop element 35 coming into contact with the transmission element.

Figure 4b illustrates a state on the boundary of the low pressure range, which is reached in response to a further increase in the external pressure or the pressure difference between the outside and the interior chamber. The center of transmission element 30 is pressed down so that region 31 of transmission element 30 touches stop element 35.

In the case of a rigid stop element, the further deflection of region 21 and the accompanying bending of measuring element 20 is limited by the contact with stop element 35.

5 Figure 4c illustrates the state in the high pressure range, when deflecting element 35 is configured as a flexible bar or bending bar. In this case, transmission element 30 deflects further, but higher pressures are necessary. The harder configuration of stop element 35 only allows first
10 measuring element 20 and stop element 35 to bend a little more, even in the case of very high pressures, so that stop element 35 also provides overload protection for measuring element 20. At the same time, the stop element 35 in the form of a second measuring element allows a measurement to be taken
15 in the high pressure range.

20 Figure 5 illustrates a further example embodiment of a measuring chip or chip 39, which is a deformation structure like chip 38 illustrated in Figure 2. Measuring element 20 having piezoresistors 21 is substantially configured like the example embodiment of the present invention illustrated in Figure 2. A subsection of chip 39 is in the form of a semienclosed diaphragm 39a and is used as an additional deformation element for measurements in the high pressure range. Like measuring element 20, semienclosed diaphragm 39a
25 carries piezoresistors 21, which are connected to a Wheatstone bridge, i.e., there is a bridge circuit on both measuring element 20 and semienclosed diaphragm 39a, which forms a second measuring element or stop element.

30 Figure 6 schematically illustrates a section of chip 39 illustrated in Figure 5. Semienclosed diaphragm 39a has a somewhat thicker shape than the first measuring element 20, which is in the form of a bar. The stiffness or elasticity of semienclosed diaphragm 39a, which is opposite to the free end of first measuring element 20, determines the measuring range,
35 while the elasticity or stiffness of first measuring element 20, which, e.g., is determined by the length and/or the width of the bar, defines the measuring range for the low pressure

range. As described above, a second bar or a tongue may also be configured analogously to the first measuring element, in place of semienclosed diaphragm 39a.

The manufacturing method of the present invention is described below with reference to Figure 1.

In this context, a cylindrical housing is initially provided, which may be manufactured from steel. The upper side of housing 11 is sealed by diaphragm 13, which is manufactured from steel and supports protuberance 42 on its lower side as a center-boss structure.

Transmission element 30 is microtechnically manufactured as a chip, so that it forms a diaphragm having a protuberance or projecting rim on the edge, which is used as a spacer for subjacent measuring chip 38, 39. The center of transmission element 30 is provided with elevations or projections in order to mechanically couple it to diaphragm structure 13 of housing 11 and couple it later to measuring element 20 and stop element 35.

Measuring chip 38, 39 is microtechnically manufactured from silicon, as well, at least one measuring element 20 being patterned in a region.

Stop element 35 is formed in another region of measuring chip 38, 39, the stop element being dimensioned so that it does not obstruct the deflection of transmission element 30 during a measurement in the low pressure range, while it comes into contact with transmission element 30 in response to a limit pressure being exceeded.

Measuring chip 38, 39 is attached to base plate 40, which includes or forms an electrical bushing. This arrangement forms the electrical contact between the measuring element(s) and the outside.

Transmission element 30 is now introduced from below, i.e., from the side opposite to diaphragm 13, into housing 11, a projection 11a in the upper edge region of housing 11 limiting its further advance. Subsequently or simultaneously to inserting transmission element 30, electrical feed-through lead 40, which has measuring chip 38, 39 attached thereto, is

inserted into housing 11. Its further advance is limited by projecting edge region 23 of transmission element 30 when electrical bushing 40, which has measuring chip 38, 39 thereon reaches its end position.

5 A ring or a sleeve 43, which matches the inner diameter of housing 11, is then inserted and welded to housing 11. Sleeve 43 is used to retain inserted elements in housing 11, the various elements being exactly positioned or fixed in place by projections 11a and sleeve 43.

10 One or more of the inserted elements and/or diaphragm 13 and/or protuberance 42 are manufactured with an aiming-off allowance, so that, prior to the insertion and fixing of the elements, the steel diaphragm or diaphragm 13 is pressed slightly outward. This arrangement compensates for manufacturing tolerances which, e.g., may be in the range of 10 μm .

15 The pressure sensor, which operates in a piezoresistive manner, is manufactured using SOI technology, and has a resolution of 0.01 bar. When stop element 35 is configured as an additional measuring element, the pressure sensor has an additional measuring range, which may be 10 to 100 times larger than the first measuring range.

20 In the example embodiments of the present invention described above, the chips have a temperature range of -50°C to 350°C , and the diaphragm functions in the temperature range of -50°C to 450°C .

25 Therefore, the pressure sensor is also suitable for measurements in the combustion chamber of engines or internal combustion engines. In general, the sensor may be used for measuring pressure in measuring ranges, which vary considerably and differ by orders of magnitude.